

## Measurements and Prediction of Fire Induced Flow Field

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Motivated by the various application of entrainment rate correlations in fire research and the large uncertainty in the efficacy of existing correlations and experimental data, the first Particle Imaging Velocimetry (PIV) based measurements of fire induced flow field around pool fires burning methanol, heptane and toluene were obtained. Air entrainment rates for 15 cm and 30 cm pool fires burning the three different fuels were calculated based on the mean velocity field. The entrainment data for the six fires could be correlated well using the fire Froude number, defined in Ref. [1] as the nondimensional parameter. A kinematic approach for the prediction of the fire induced flow field, following Ref. [2], was extended to the present fires. The driving processes for the entrainment flow, namely the volumetric heat release and the baroclinic vorticity generation, were evaluated based on correlations of buoyant diffusion flame structure in the literature [2, 3]. The predicted entrainment velocities were substantially higher than the measurements but were in qualitative agreement with the data. Based on this, the heat release rate and vorticity correlations used in the analysis were corrected by using a smaller radius for the  $1/e$  point in the velocity profile. The modified predictions were in better agreement with the experimental data. Therefore, further evaluation of the kinematic approach with proper heat release rate and vorticity distributions is warranted.

The upper half of Fig. 1 represents the measured mean entrainment flow field around the 30 cm toluene pool fire. The vectors represent the mean convection velocities. Also shown in the figure is an instantaneous visible flame boundary. Large vertical velocity components at the elevation of the fuel surface, at radii larger than that of the pool edge, show that considerable air is entrained from regions below the elevation of the fuel surface. At a given height, both axial and radial velocities increase with smaller radial distance from the flame, and at a given radial location, the velocity only changes slightly with the axial distance. At the farthest radial location ( $r = 27$  cm) the vertical velocity component is comparable to the radial velocity component.

The past correlations for heat release rate and vorticity distributions require that the radius of the  $1/e$  point in the velocity profile be approximately 17.5 cm as shown in the bottom half of Fig. 1. With these correlations, a substantial overprediction of both the radial and axial velocity components was observed. Since the vorticity and heat release rate data for the present fire are not available, a reduction in the radius of the  $1/e$  point in the velocity profile to 9.5 cm was utilized. The resulting predictions of velocity vectors are shown in the bottom half of Fig. 1. These are in reasonable qualitative and quantitative agreement with the measurements. The discrepancies between the measurements and predictions in Fig. 1 are mainly in the vertical velocity component. To resolve these differences, the volumetric heat release rate distribution and the vorticity distribution need to be measured for conditions representative of the present fires.

### References

- [1] Delichatsios, M. A., *Combust. Flame* 70:33-46 (1987).
- [2] Baum, H. R., and McCaffrey, B. J., *Fire Safety Science - Proceedings of the Second International Symposium*, Tokyo, Japan.
- [3] McCaffrey, B. J., National Bureau of Standards (currently NIST) Report No. NBSIR 82-2473, 1982.

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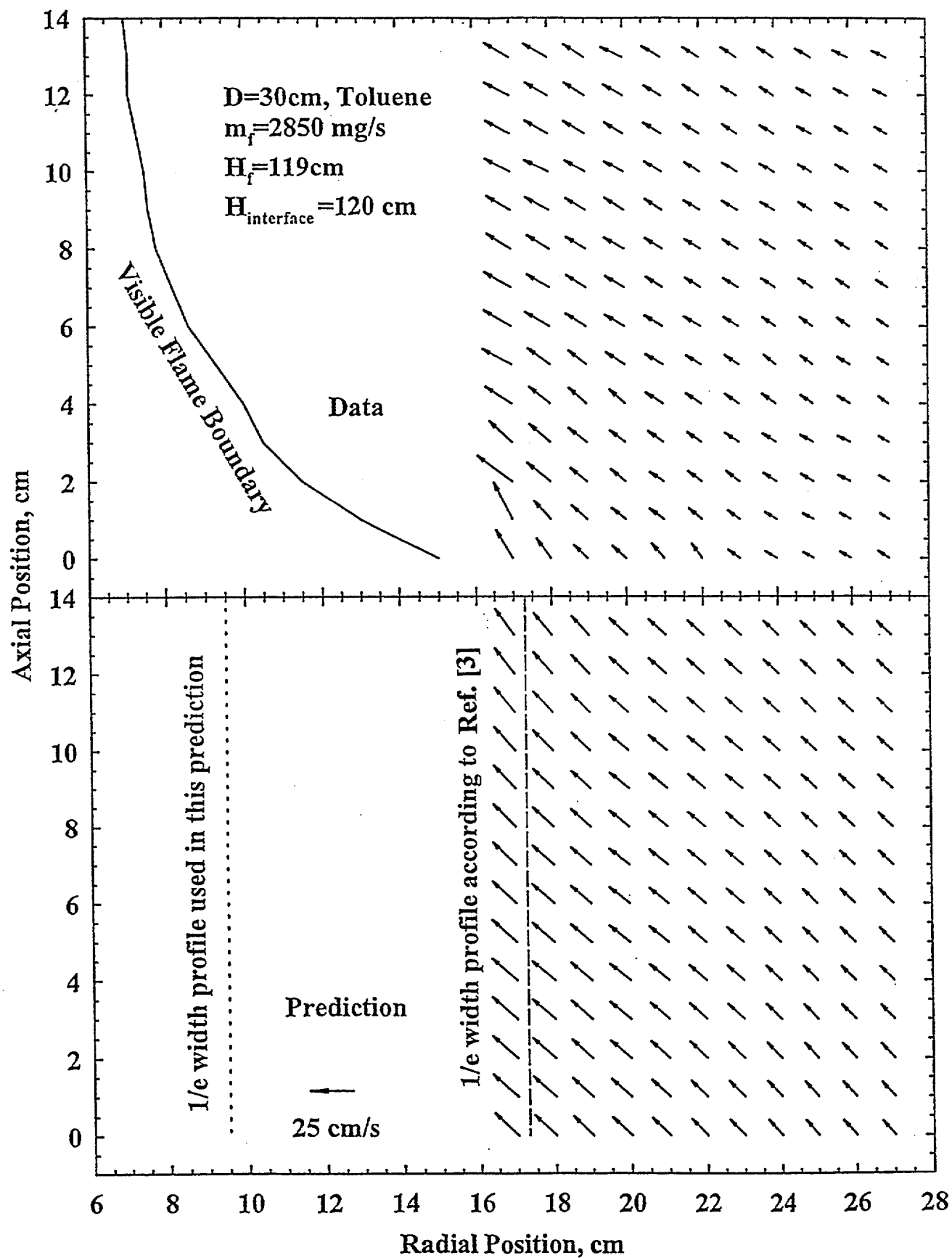


Figure 1: Measurements and Predictions of Fire Induced Flow Field around a 30 cm Toluene Pool Fire